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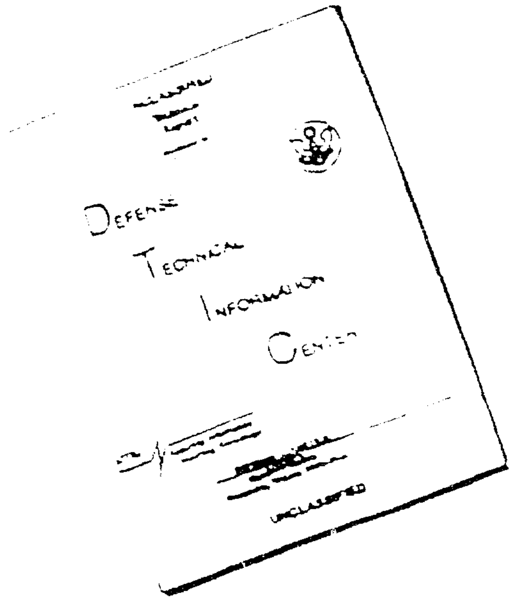

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NRL Memorandum Report 1769

Project ARTEMIS Acoustic Source

Acoustic Test Procedure

[Unclassified Title]

R. H. FERRIS AND C. R. ROLLINS

Propagation Branch
Sound Division

June 5, 1967

NAVAL RESEARCH LABORATORY
Washington, D.C.

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ABSTRACT

Acoustic tests of the completed ARTEMIS acoustic source were conducted in Northwest Providence Channel in November 1965. A rigid 190 foot hydrophone boom pivoted at the base of the array structure enabled stable and accurate positioning of hydrophones at points in a vertical plane from 2.5 degrees above to 22.5 degrees below the acoustic axis of the source.

The transfer function between the input to the amplifiers and the hydrophone output was measured over the frequency range from 300 to 500 hertz for two types of signals, continuous wave and pseudorandom sequences. Continuous wave measurements were made using conventional phase and amplitude measuring instrumentation whereas the measurements with pseudorandom sequences were performed with a cross-power spectrum analyzer. The cross-power spectrum analyzer was also used to obtain correlation functions between the signal input and acoustic output. Twenty transducer elements were instrumented with accelerometers and appropriate instrumentation was provided to permit monitoring of transducer element spring deflections, since the transducer springs are the critical factor limiting the allowable power input.

This report includes a description of instrumentation, test procedures, and analysis of the methods employed.

PROBLEM AUTHORIZATION

ONR RS 046
NRL Problem 55S02-11

PROBLEM STATUS

This is an interim report on one phase of this project. Work is continuing.

INTRODUCTION

The completed and modified ARTEMIS acoustic source was tested[1] in July 1964 to determine its operating characteristics and define the maximum allowable power input as a function of operating frequency.

Measurement of the electro-acoustic transfer function requires a means of placing monitor hydrophones at accurately known and stable locations in the acoustic field. A further requirement is that the hydrophones be located a sufficient distance from the source to approximate far-field conditions. To meet these conditions, a rigid 190 foot hydrophone boom was constructed. The boom, when attached to the transducer array, provided a stable and movable support for monitor hydrophones.

Acoustic tests, employing the 190 foot hydrophone boom, were conducted in Northwest Providence Channel during November, 1965. Tests were conducted with the transducer array, with boom attached, suspended beneath the source ship, the USNS MISSION CAPISTRANO (T-AG 162), at a depth of 600 feet. The transfer functions between the input to the amplifiers and the hydrophone outputs were measured over the frequency range of 300 to 500 hertz for propagation angles relative to the acoustic axis of 2.5 degrees above the axis through 22.5 degrees below the axis. Correlation functions between the signal input and acoustic output were also obtained as were records of a sampling of transducer element spring deflections.

The following sections of this report describe details of the test procedures and of the instrumentation employed as well as analyses of the experimental methods. Results of the tests are described in a separate report[2].

HYDROPHONE BOOM

To achieve phase measurement accuracy of ±3°, it was necessary to position the hydrophones with a stability of ±0.1 foot in range. Positional stability of this order at distances from the array sufficient to approach the far-field required design and fabrication of a rigid 190 foot boom. The boom was attached and pivoted from the center of the lower edge of the array face, as

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1. NRL Confidential Memorandum Report 1648 "Test of Project ARTEMIS Acoustic Source", R. H. Ferris, September 1965.

2. NRL Confidential Report 6534 "Project ARTEMIS Acoustic Source Performance Characteristics"; R. H. Ferris, C. R. Rollins, ____ 1966.

shown in Fig. 1. A close-up view of the pivot point is shown in Fig. 2. The boom was supported by a single wire rope attached at a point approximately 50 feet out from the base and extending to a hoisting drum mounted on top of the array structure. Figure 3 is a photograph of the hoisting drum and the attachment of the wire rope to the boom. The boom pivoted in a vertical plane only. The hoisting drum was arranged with three locked positions to provide for three fixed operating depression angles of the boom. The drum was also capable of raising the boom to a stowed position against the face of the array.

A 16-foot spar was attached at its midpoint to the end of the boom, making an angle of 98 degrees with the top edge of the boom in the vertical plane (see Fig. 1). Three hydrophones were attached to the spar: one at each end and one in the center. The three operating positions of the boom provided hydrophone positions relative to the array as shown in Table A-1. In addition, measurements were obtained at intermediate boom positions for a few frequencies.

The boom was fabricated in ten sections which could be bolted together. The 28-foot 2-inch long base section, and two of the 20-foot long sections, together with the mounting base plate and hoisting equipment, were assembled and installed at dockside with the three boom sections in the vertical (stowed) position as shown in Fig. 4. On station, the array was lowered, and the additional eight boom sections were bolted in place as the top of each installed section neared water level. The hydrophones were assembled to the spar, and then the assembly was bolted to the boom end section. The hydrophone cables were lashed to the boom during assembly and routed from the hydrophones to the base of the boom, to the top of the array structure, and then to the deck of the ship. Between the array and the deck of the ship, the hydrophone cables were lashed at 100-foot intervals to the double-armored instrumentation cable of the source. A fourth electrical cable, which connected a position sensor (synchro) at the base of the boom, was routed with the hydrophone cables and provided a direct readout of the angle of the boom relative to the array.

When the boom and hydrophone assembly was complete, the array was lowered until the boom was clear of the ship's bottom, and a tagline over the side of the ship was used to pull the boom away from its stowed position against the array face. The hoisting drum, powered from a wire rope fairleaded to a deck winch, lowered the boom to the first boom position. The array was then raised until the hoisting drum depth was 50 feet, and divers inspected the locking mechanism on the drum. The array was then lowered to the operating depth of 600 feet.

To change the boom position, the array was raised to the 50-foot depth and divers released the locking mechanism. The boom was adjusted to the new position by means of the winch and hoisting drum, and the divers again checked the locking mechanism before the array was lowered to operating depth. Upon completion of the measurement program, the boom was disassembled as it emerged through the array well. Intermediate raising of the array did not require disassembly of the boom except for removal of the hydrophone spar. A photograph of the raised boom during transit is shown in Fig. 5.

Operation of the boom proved very successful and no difficulty in assembly or handling was encountered.

ACOUSTICAL MEASUREMENTS

Three types of acoustical measurements were made between the console input and hydrophone output as follows:

1. Transfer function measurements (amplitude and phase) using continuous-wave sinusoidal excitation.

2. Transfer function measurements (amplitude and phase) using pseudorandom-signal excitation.

3. Cross-correlation measurements between the electrical signal input and the hydrophone outputs.

In addition, measurements of the radiated noise spectrum were made. The hydrophone sensitivities were as follows: $h_A = 94.5$ db, $h_B = 94.3$ db, $h_C = 94.5$ db. Cable loss of 0.6 decibel was included when the data were adjusted for hydrophone sensitivity and range.

Prior to obtaining data at any operating position, a reverberation check was made by transmitting 50-millisecond pulses at one-second intervals and observing and photographically recording the reverberation level. Reverberation levels were negligible (less than one percent) except for hydrophone positions on the beam null where the reverberation level approached ten percent in some cases. However, in all cases, the difference between continuous-wave amplitude and pulsed amplitude was negligible. Therefore, continuous signals were used for the sinusoidal transfer-function measurements.

Continuous-Wave Transfer Function Measurements - Figure 6 is a block diagram of the instrumentation used to obtain the continuous-wave transfer function measurements. The objective of the measurements was to obtain the far-field transfer function $H_\theta(\omega)$ referred to zero range; i.e., with the propagation delay removed. This was accomplished by setting the delay circuit τ_p equal to the calculated acoustic propagation time. Thus, the phase counter start pulse, originating in the reference signal, was delayed by a time equal to the propagation time, and the measured phase corresponded to the hydrophone phase referred to zero range. These measurements were made for nine fixed hydrophone positions plus intermediate positions for some frequencies. (Three fixed hydrophone positions for each boom position. Refer to Table A-1). The measurements were obtained for frequencies between 300 and 500 hertz, and for current levels from 20 to 120 amperes, as shown in Table A-2. These ranges of frequency and current were selected to conform to the maximum allowable power input to the transducer array.

Pseudorandom-Signal Transfer Function Measurements - Transfer function measurements were made using broadband (25-percent bandwidth) phase-modulated pseudorandom signals in order to determine if transducer nonlinearities affect the transfer function for different forms of signals. These signals were generated using a linear shift register with shift rates of 50 hertz and 100 hertz. The 50-hertz shift rate was used with an 11-bit register and the 100-hertz rate was used with a 12-bit register to produce a signal length of 42 seconds in each case. The shift-register output caused a 180-degree phase shift in the 400-hertz carrier, thus producing a signal with a 400-hertz frequency and pseudorandom phase-reversal modulation. (The 11-bit register code[3] was 5205E and the 12-bit register code was 10123F.) Figure 7 is a plot of the power spectra for the two signals.

All measurements were made at four-hertz increments of frequency from 350 through 450 hertz with an analyzing bandwidth of four hertz, a transducer depth of 600 feet, and an input current of 85 amperes. Frequency-modulated magnetic tape recordings were made of all hydrophone outputs, together with the delayed reference, clock frequency, and amplifier output voltage. Block diagram of the pseudorandom transfer function instrumentation and of the spectrum analyzer are shown in Figs. 8 and 9 respectively. Fig. 10 is a photograph of the pseudorandom generator (left) and spectrum analyzer (right) installed on the USNS MISSION CAPISTRANO.

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[3]. W. Wesley Peterson "Error Correcting Codes", The MIT Press, 1961.

The desired transfer function is the far-field hydrophone output referred to zero range divided by the signal generator voltage $(V_{0\theta}/V_G)$. Since the hydrophone voltage is directly proportional to the pressure, the transfer function thus measured is related by a constant to the hydrophone pressure to input voltage ratio. Letting τ_p represent the propagation delay, we have:

$$V_G'(\omega) = V_G(\omega)e^{-j\omega\tau_p} ,$$

$$V_{h\theta} = V_{0\theta}e^{-j\omega\tau_p} ,$$

$$H_\theta(\omega) = \frac{V_{0\theta}(\omega)}{V_G(\omega)} = \frac{V_{0\theta}(\omega)e^{-j\omega\tau_p}}{V_G(\omega)e^{-j\omega\tau_p}} = \frac{V_{h\theta}(\omega)}{V_G'(\omega)} .$$

The transfer function between two points in a linear system can be shown to be given by the following relationship:

$$H(\omega) = \frac{S_{xy}(\omega)}{S_{xx}(\omega)}$$ (see Ref. [4])

where

$S_{xy}(\omega)$ = cross-power spectral density between inputs x and y, and

$S_{xx}(\omega)$ = power spectral density of input x.

Therefore, the analyzer outputs giving the real and imaginary parts of $S_{xy}(\omega)$ provide the correct amplitude and phase ratios for determining the desired transfer function between the input and hydrophone output, when the actual analyzer inputs are V_G' and $V_{h\theta}$.

The cross-power spectral density, $S_{xy}(\omega)$, is defined as:

---

4. "Probability, Random Variables, and Stochastic Processes", Athanasios Papoulis, McGraw Hill, 1965.

$$S_{xy}(\omega) = \lim_{T \to \infty} \frac{X(-\omega)Y(\omega)}{T} ,$$

where

$$X(\omega) = \int_0^T x(t)e^{-j\omega t} dt = A(\omega) + jB(\omega),$$

$$Y(\omega) = \int_0^T y(t)e^{-j\omega t} dt = C(\omega) + jD(\omega).$$

$$A(\omega) = \int_0^T x(t)\cos\omega t dt = Re[X(\omega)],$$

$$B(\omega) = \int_0^T x(t) \sin\omega t dt = Im[X(\omega)],$$

$$C(\omega) = \int_0^T y(t)\cos\omega t dt = Re[Y(\omega)],$$

$$D(\omega) = \int_0^T y(t)\sin\omega t dt = Im[Y(\omega)].$$

Since $A(\omega)$ is an even function and $B(\omega)$ is an odd function,

$$X(-\omega) = A(\omega) - jB(\omega).$$

Therefore,

$$S_{xy}(\omega) = \lim_{T \to \infty} \frac{A(\omega)C(\omega) + B(\omega) + j[A(\omega)D(\omega) - B(\omega)C(\omega)]}{T} .$$

It can be seen from the block diagram (Fig. 9) that the analyzer performs the above operations, operating, however, over a finite integration time T_o. The pseudorandom sequences employed were of 42 seconds duration and the integrators were gated to integrate over this interval and then hold for a manual readout.

Cross-Correlation Measurements - Figure 11 is a block diagram of the instrumentation used to obtain cross-correlation measurements between the pseudorandom signal generator and the hydrophone output signals. The delay, τ, was adjustable in increments of 0.2 milliseconds, with a range sufficient to obtain results for $\tau = \pm 30$ milliseconds. The pseudorandom signal generator used was the same as used for the cross-spectrum measurements. The signals employed were phase-modulated pseudorandom sequences of 400-hertz center frequency and modulation rates of 50 and 100 hertz. Cross-correlation measurements were made with the signal from each hydrophone at each boom position. In addition, the generator and hydrophone powers were measured for use in the normalized cross-correlation coefficient.

Noise Spectrum Measurements - Noise spectrum measurements were obtained at the output of one of the monitor hydrophones through the use of a wave analyzer having a seven hertz analyzing bandwidth. Measurements were made over the frequency range of from 60 hertz to 15 kilohhertz both with the array energized at 420 hertz and with the array not energized. When the array was energized a notch filter of known insertion loss and tuned to 420 hertz was inserted between the hydrophone output and the wave analyzer.

FAR FIELD MEASUREMENT ACCURACY

The acoustical measurements were intended to represent far-field values. In order to estimate the degree to which the measurements approximated far-field values a computation was made of the field of a hypothetical array consisting of 160 point source projectors uniformly distributed in a plane rectangular area having the dimensions of the ARTEMIS array. One hundred sixty points was proved by an iterative process, to closely approximate an array having an infinite number of in-phase projectors. The computation was made at a frequency of 400 hertz for a hydrophone distance from the center of the array of 190 feet (the approximate range of the experimental measurements) and also at far-field (infinite range). The far-field amplitude was normalized to zero decibels on the acoustic axis and the phase was referred to zero degrees on axis. The results are plotted in Fig. 12. It can be seen that the amplitude at a range of 190 feet approximates the far-field amplitude to within 0.5 decibels for angles in the major lobe out to 10 degrees. The peak amplitude of the first minor lobe is also accurate to within approximately 0.5 decibels. The first null, however, shows a large divergence from far-field values. The phase computations show a significant departure from far-field values at nearly all angles. However, the significant characteristics of the phase data is whether or not the phase error is a linear function of frequency since an error which is a linear function of frequency represents only a time shift and does not introduce phase distortion. Table 3 lists the maximum deviation from a linear phase shift within the band of

frequencies from 350 to 450 hertz and for depression angles from zero to 20 degrees for the far-field phase error illustrated in Fig. 12. It can be seen that the deviation from a linear shift is negligible for angles in the major lobe out to 6 degrees. At larger angles the deviation increases to 25 degrees and some phase distortion in broadband signals could be expected at a range of 190 feet that would not be present in the far field.

TRANSDUCER ELEMENT SPRING DEFLECTIONS

Prior to assembly and use of the hydrophone boom, the array was submerged to a depth of 600 feet and the spring deflections of 20 instrumented elements were observed for the purpose of determining allowable power levels for various signal types. Figure 13 is a block diagram of the ARTEMIS signal path. The system could be excited from the pseudorandom signal (PRS) generator, or from the sinusoidal generator. The sinusoidal signal could be gated, using a General Radio toneburst generator. A description of the PRS generator is given in the section on acoustical measurements.

Previous experimental results indicated the need for more information about the maximum spring deflection of the TR-11C variable reluctance element when excited by modulated waveforms. Since maximum power into the array is limited by the maximum allowable spring deflections, this measurement is of considerable importance. Twenty transducer elements were instrumented as shown schematically in Fig. 14. The three accelerometers, a_0, a_1, a_2, were located so that

$$\int\int(a_0 + a_1)dt\, dt$$

gives the deflection of the top spring and

$$\int\int(a_0 + a_2)dt\, dt$$

gives the deflection of the bottom spring.

Figure 15 is a block diagram of the instrumentation system used to obtain the spring deflection data, and a photograph of the installed instrumentation is shown in Fig. 16. The accelerometer cables were terminated in a junction box mounted on the array structure. An accelerometer pair (one inner and corresponding outer accelerometer) was selected by the remotely controlled stepping switches. Each signal was amplified by a preamplifier located in the

junction box and then transmitted via shielded cable to the instrumentation room aboard the ship. After high-pass filtering, each channel was integrated twice with respect to time, band-pass filtered, and the inner and outer channels were added to give the spring deflection, which was displayed on an oscilloscope for peak-to-peak measurement. The instrumented elements were distributed in the array as shown in Fig. 17.

SUMMARY

An acoustic calibration of the ARTEMIS source was performed during November 1965. The data obtained consisted of transfer functions using both continuous wave and pseudorandom signals over a frequency band from 300 to 500 hertz and for angles in a vertical plane through the acoustic axis from 2.5 degrees above the axis to 22.5 degrees below the axis. Additional data included cross-correlation functions between the signal input to driving amplifiers and the hydrophone output, a sampling of transducer element spring deflections, and noise spectrum measurements.

Monitor hydrophones were positioned accurately and stably by the use of a 190 foot hydrophone boom pivoted at the base of the array structure. The boom, which was designed for this purpose, proves to be a practical device which was assembled and controlled without difficulty. The distance of the monitor hydrophones from the center of the array face was approximately 190 feet varying slightly depending on boom position. This range is sufficient to permit a good approximation to far field conditions for the major lobe within the minus three decibel points. At larger angles relative to the acoustic axis the approximation is poorer, particularly in the vicinity of the first null.

Measurement of the transfer function with both steady state sine waves and pseudorandom signals is desirable since it is known that electro-acoustic transducers are not strictly linear devices.

TABLE A-1

HYDROPHONE POSITIONS FOR 190-FOOT BOOM POSITIONS

	Top Hydrophone A			Center Hydrophone B			Bottom Hydrophone C		
	Pos. #1	Pos. #2	Pos. #3	Pos. #1	Pos. #2	Pos. #3	Pos. #1	Pos. #2	Pos. #3
Distance from hydrophone to center (ft.)	189.23	192.82	198.76	190.40	193.97	199.85	189.29	192.84	198.64
Perpendicular distance from hydrophone to array face (ft.)	189.04	192.10	189.51	190.40	192.31	187.80	189.10	189.89	183.56
Depression Angle re Acoustic axis (degrees)	-2.55	+4.97	+17.55	0	+7.5	+20	+2.58	+10.03	+22.46

TABLE A-2

Frequency hz	I_1 amperes	I_2 amperes	I_3 amperes	I_4 amperes	I_5 amperes	I_6 amperes
300	20	40	-	-	-	-
310	20	40	-	-	-	-
320	20	40	-	-	-	-
330	20	40	-	-	-	-
340	20	40	60	-	-	-
350	20	40	60	80	100	120
355	20	40	60	80	100	120
360	20	40	60	80	100	-
365	20	40	60	80	100	120
370	20	40	60	80	100	120
375	20	40	60	80	100	120
380	20	40	60	80	100	120
385	20	40	60	80	100	120
390	20	40	60	80	100	-
395	20	40	60	80	-	-
400	20	40	60	80	-	-
405	20	40	60	80	-	-
410	20	40	60	80	-	-
415	20	40	60	80	100	-
420	20	40	60	80	100	-
425	20	40	60	80	-	-
430	20	40	60	-	-	-
435	20	40	60	-	-	-
440	20	40	60	-	-	-
445	20	40	60	-	-	-
450	20	40	-	-	-	-
460	20	40	-	-	-	-
470	20	40	-	-	-	-
480	20	40	-	-	-	-
490	20	40	60	-	-	-
500	20	40	60	-	-	-

TABLE A-3

Depression Angle	Worst Deviation from Linear Phase Shift Over 350–450 Hz Band
0°	0.4°
6°	2.0°
12°	25.0°
20°	25.0°

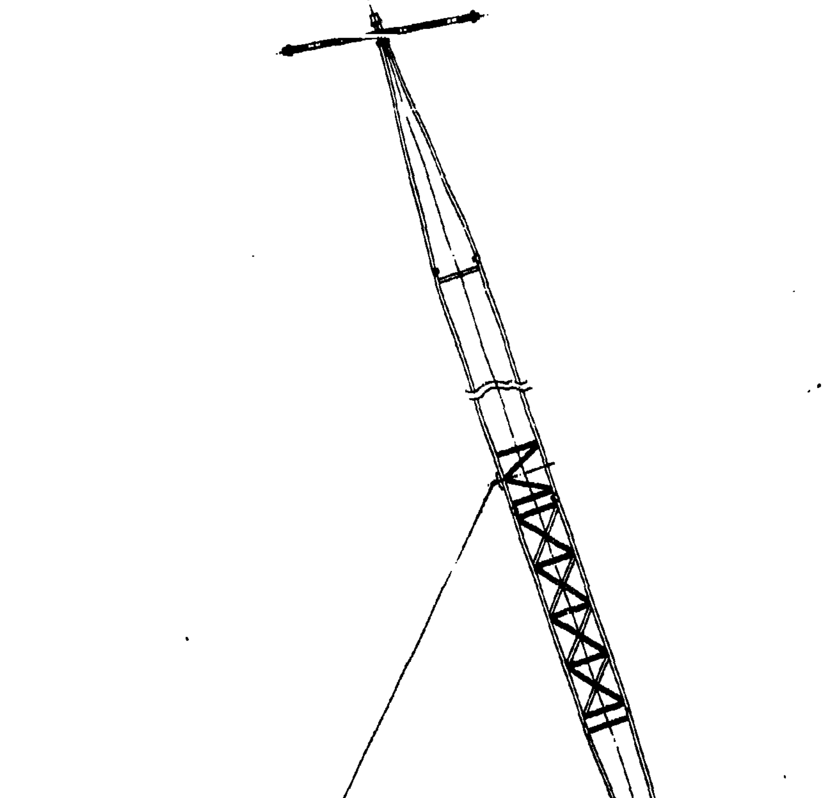

Fig. 1 - Drawing of hydrophone boom

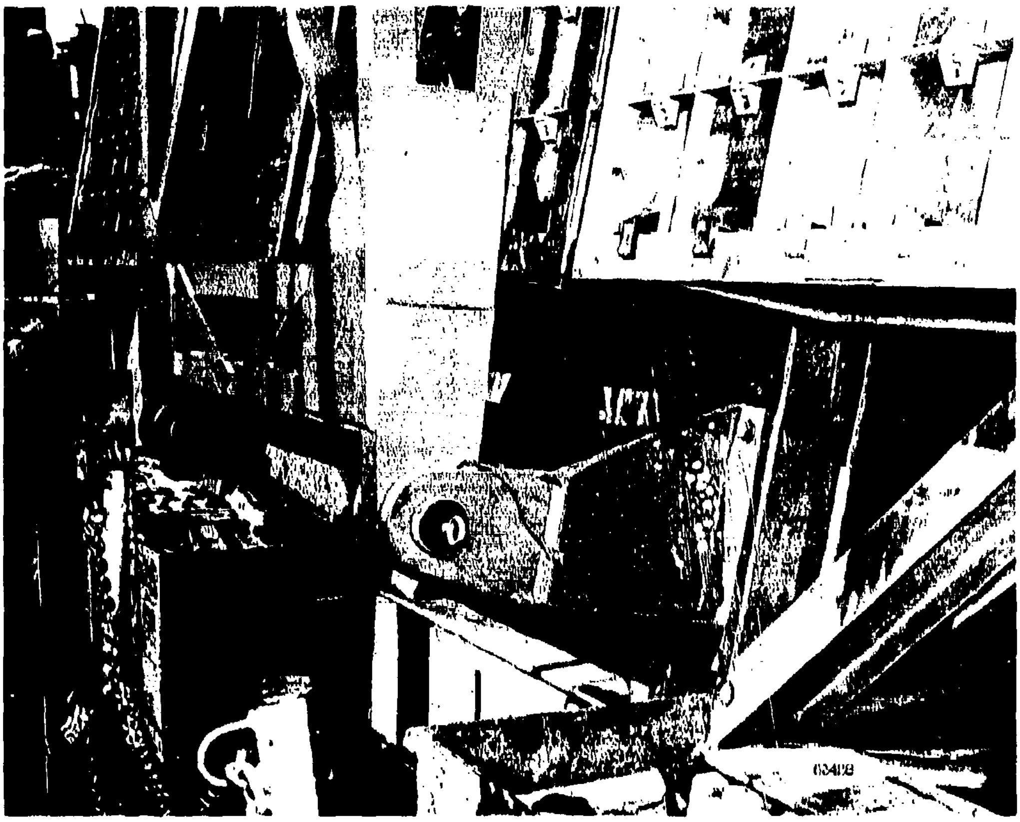

Fig. 2 - Base plate, pivot, and base section of boom

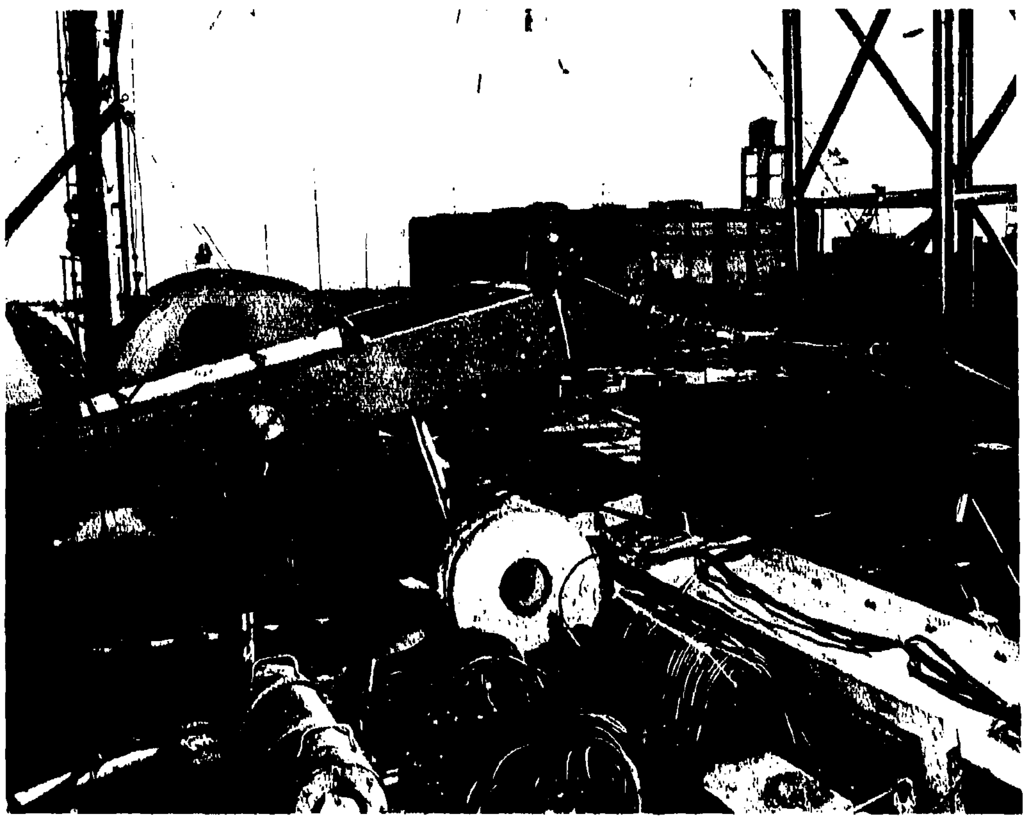

Fig. 3 - Hoisting drum and cable

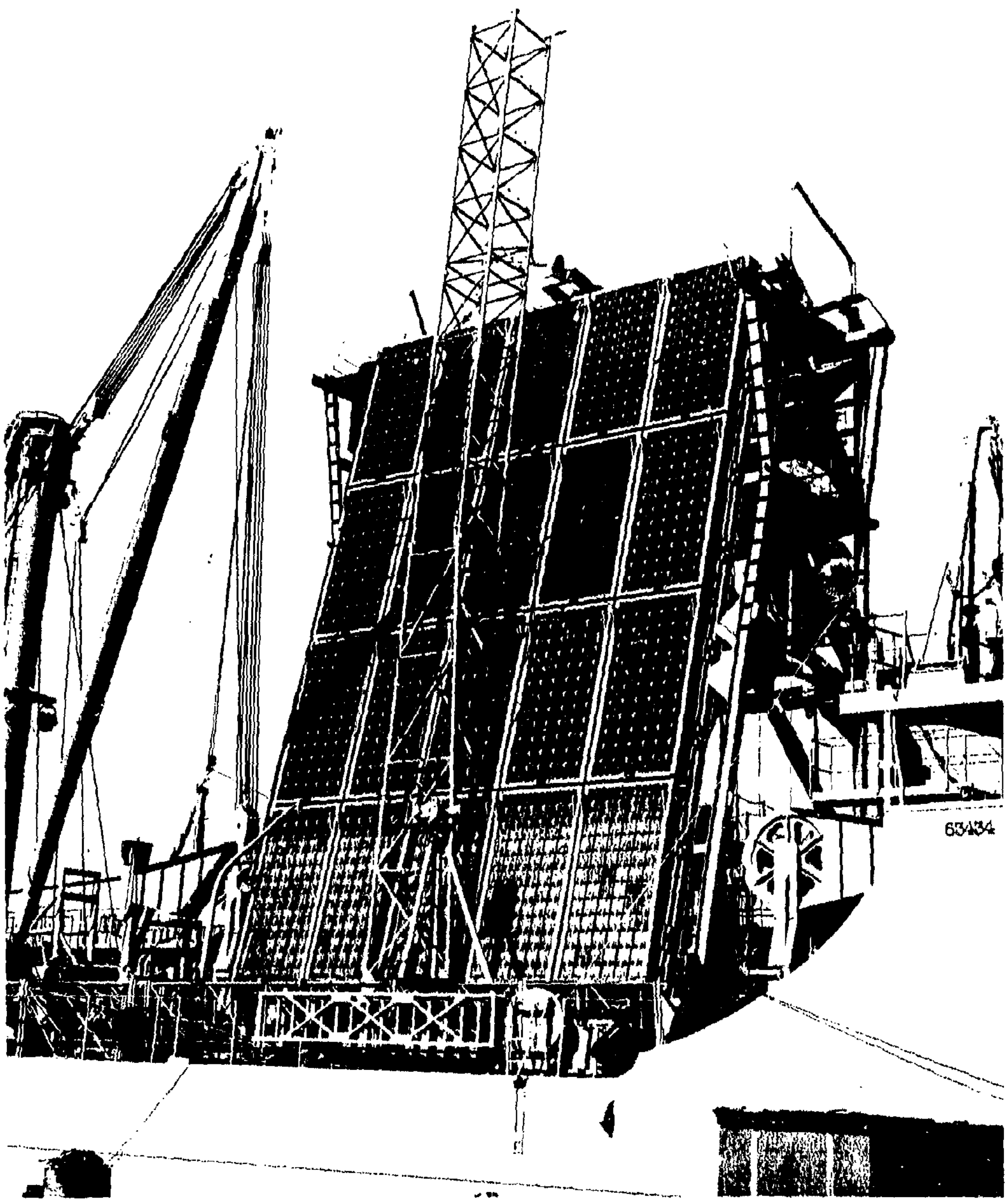

Fig. 4 - Three boom sections attached to array

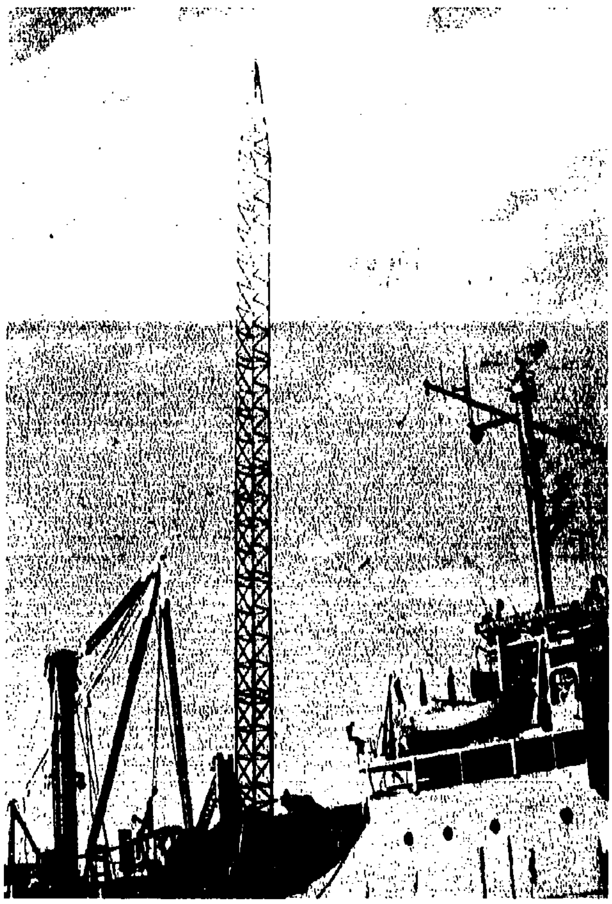

Fig. 5 - Hydrophone boom raised for transit

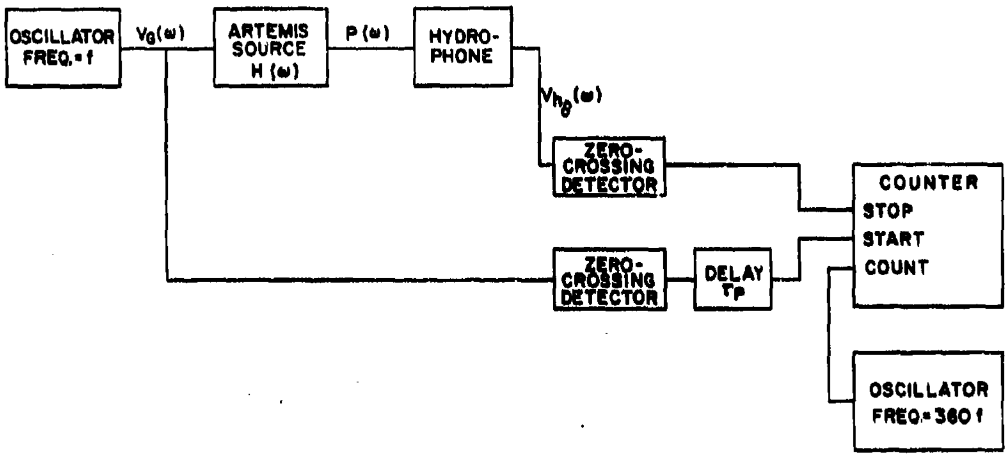

Fig. 6 - Block diagram of continuous-wave transfer function instrumentation

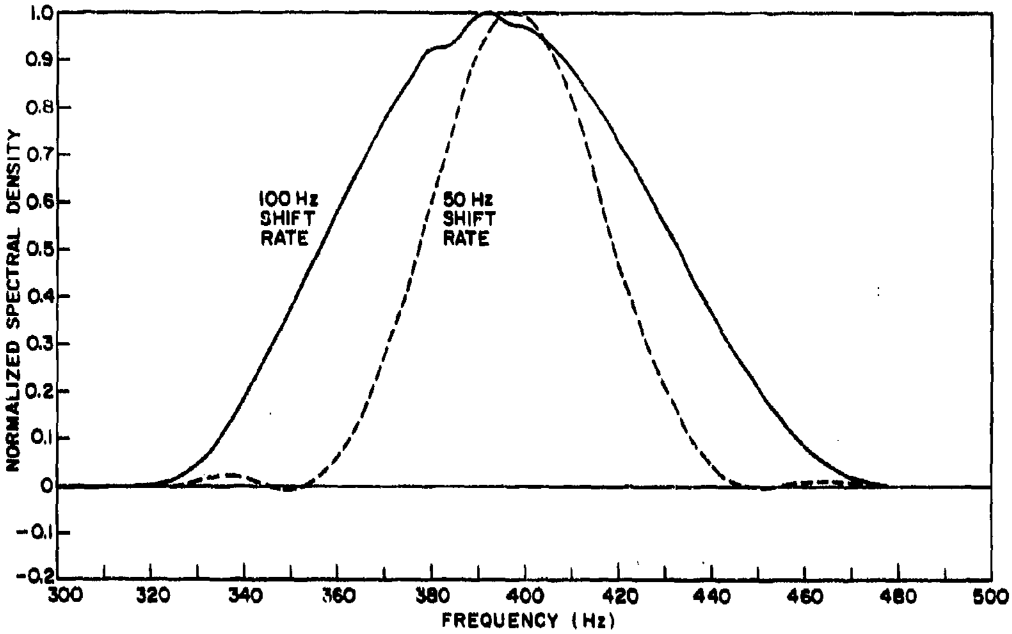

Fig. 7 - Power spectra of pseudorandom signals

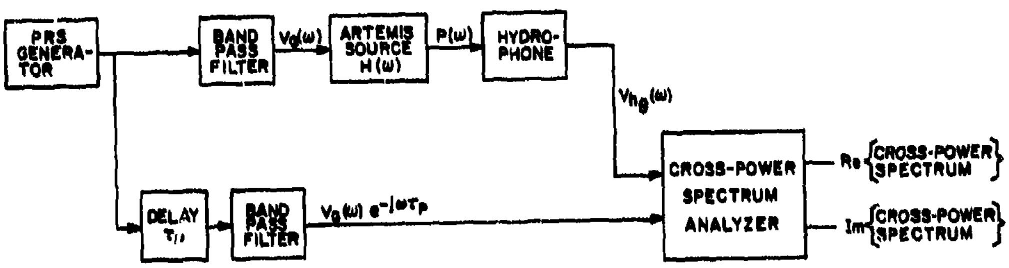

Fig. 8 - Block diagram of pseudorandom signal transfer function instrumentation

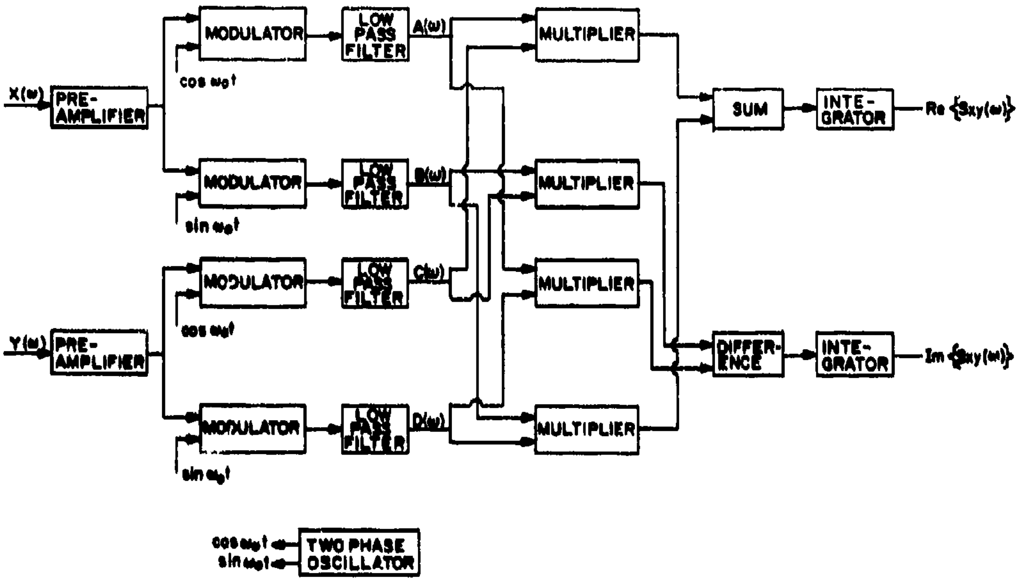

Fig. 9 - Block diagram of spectrum analyzer

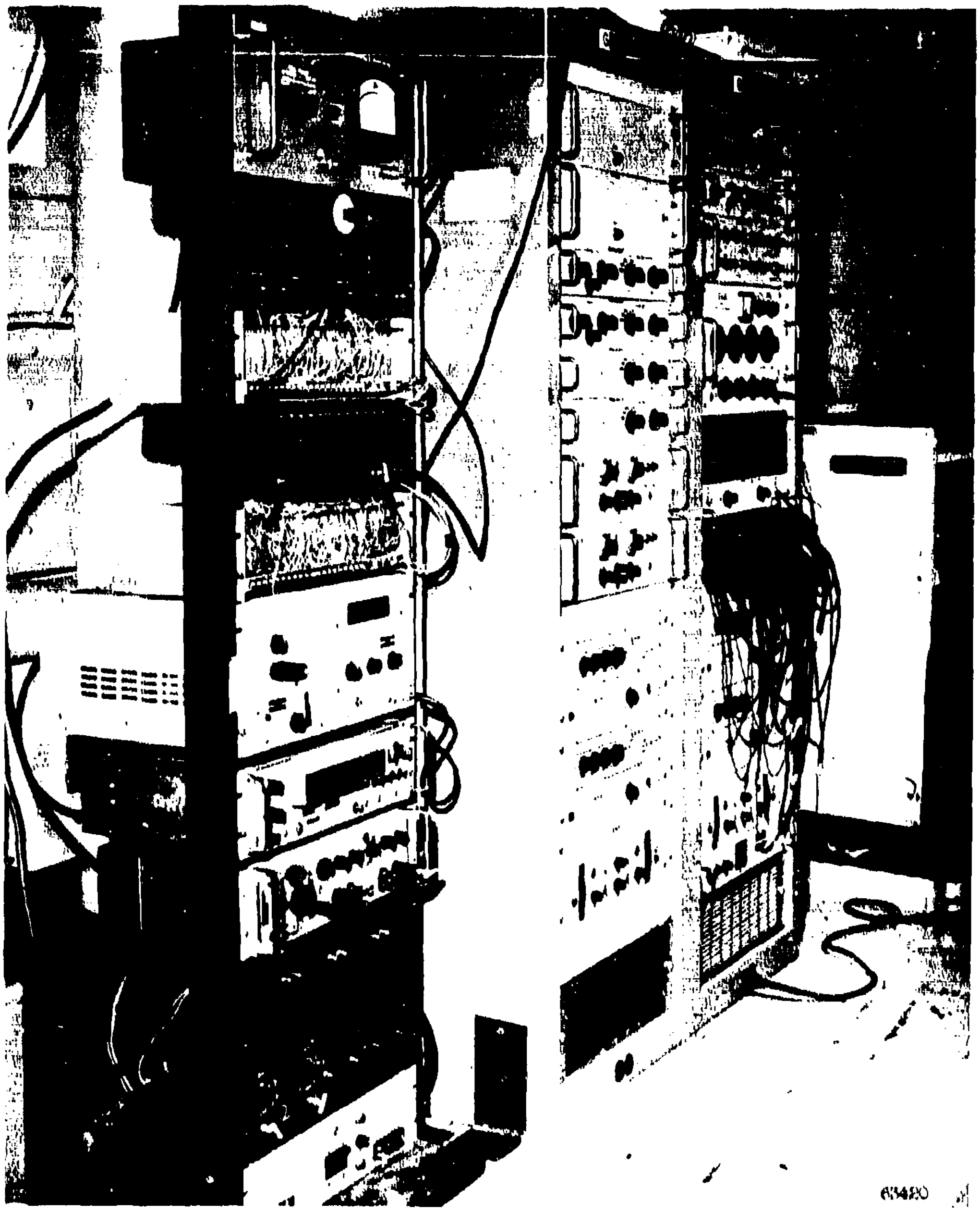

Fig. 10 - Pseudorandom signal generator and cross-spectrum analyzer

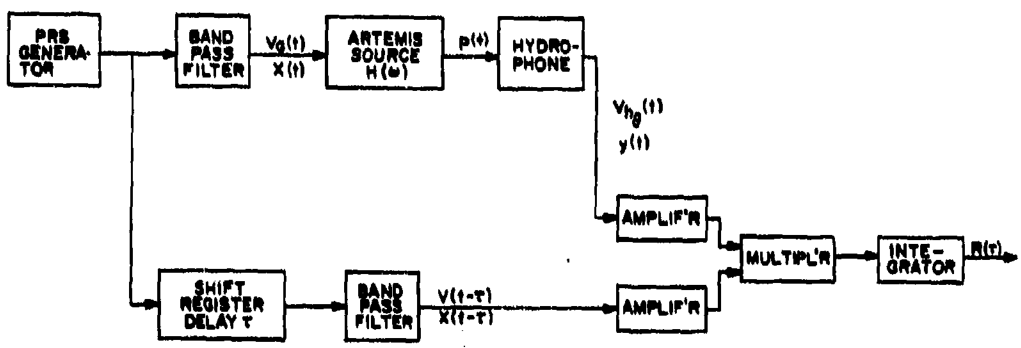

Fig. 11 - Block diagram of instrumentation system for cross-correlation measurements

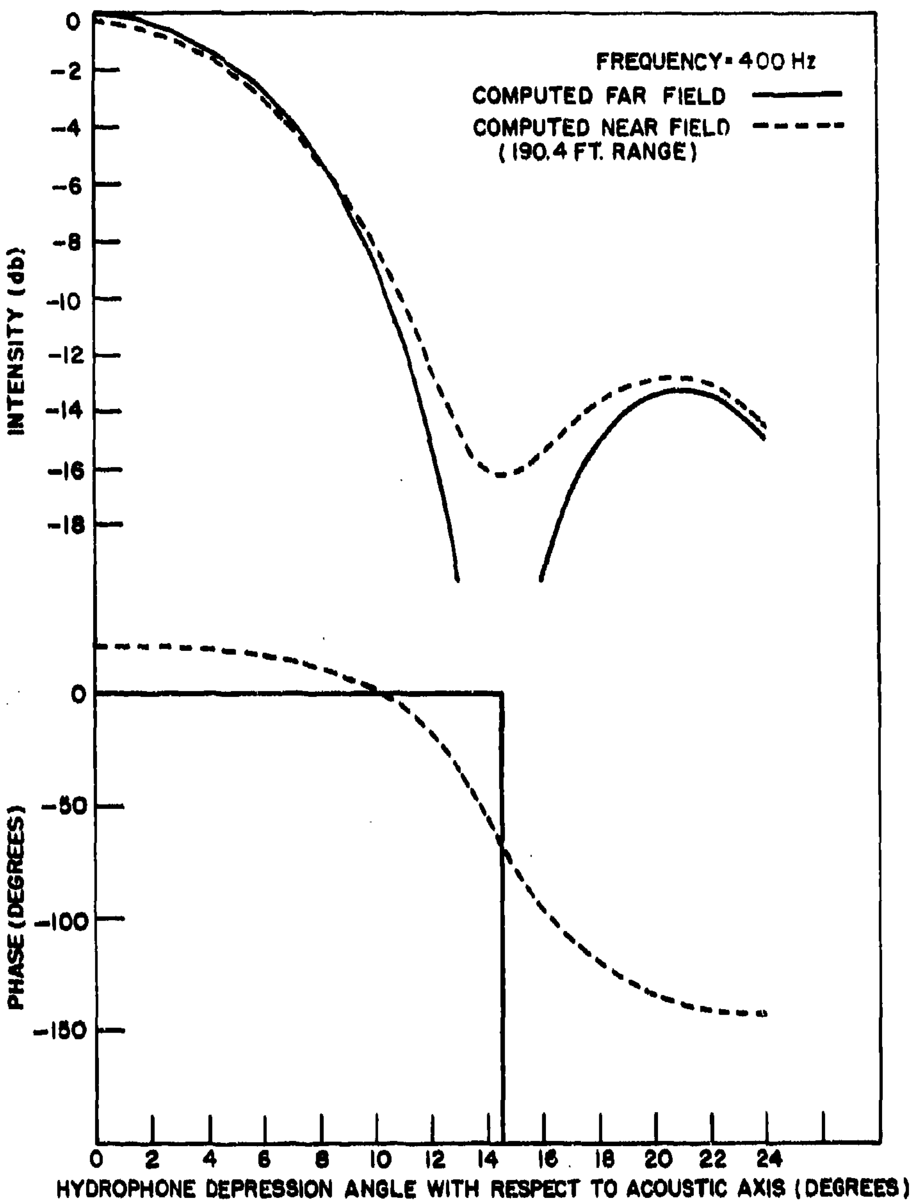

Fig. 12 - Computed patterns at far field and at a range of 190.4 ft

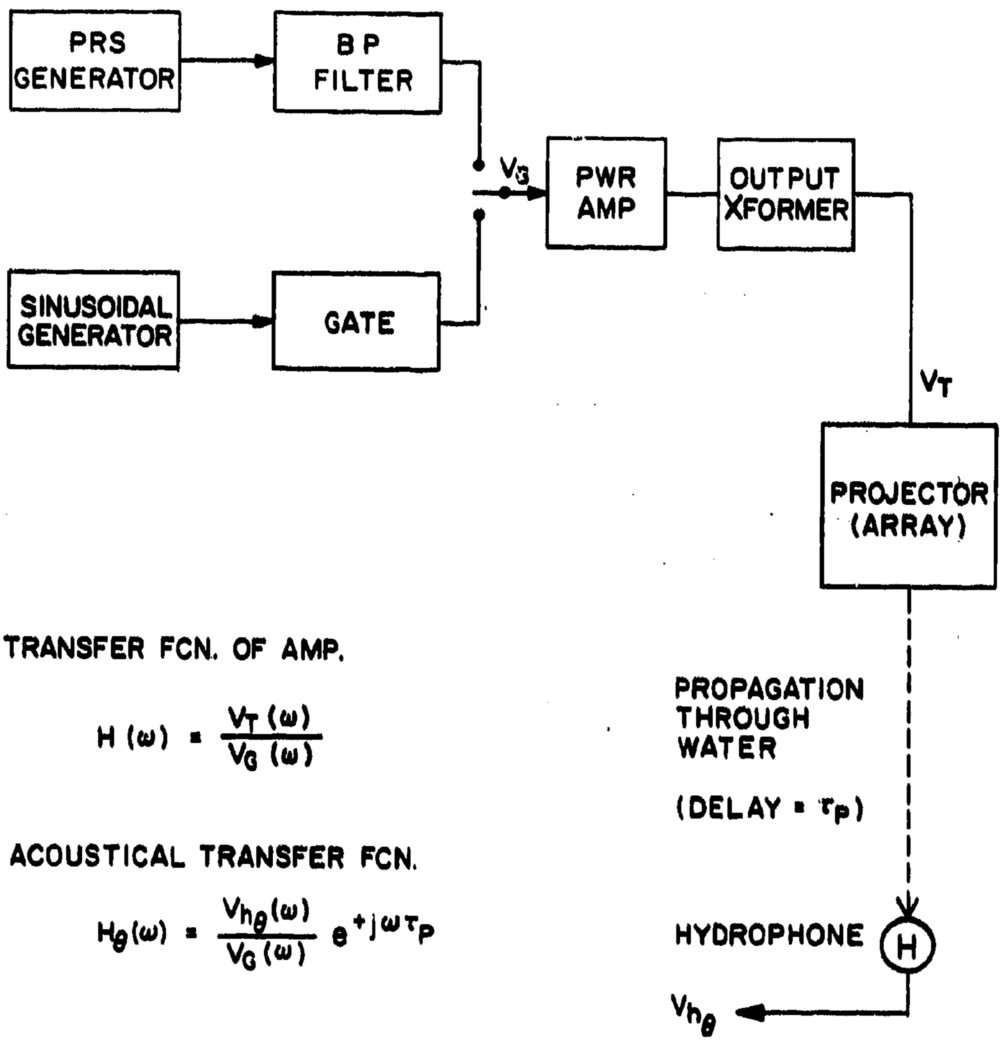

Fig. 13 - Block diagram of ARTEMIS signal path

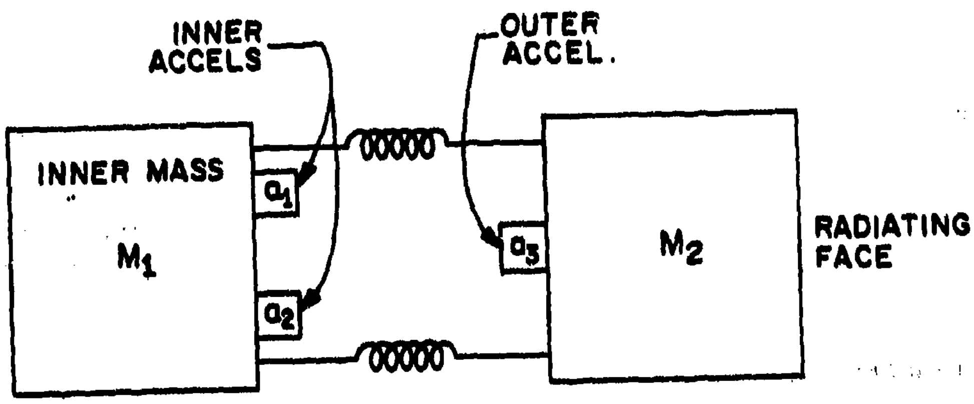

Fig. 14 - Schematic representation of TR-11 element with accelerometer locations

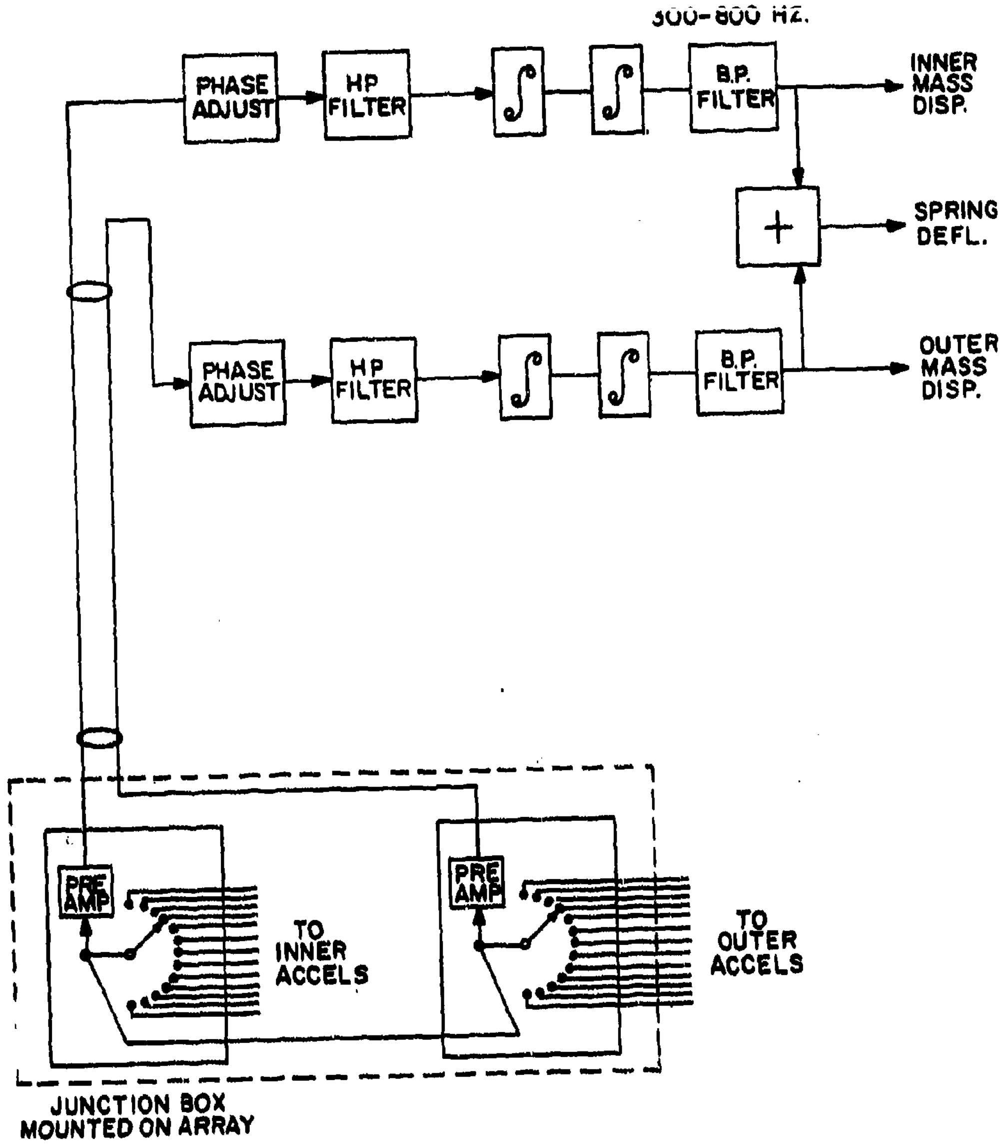

Fig. 15 - Block diagram of the instrumentation system for obtaining spring deflections

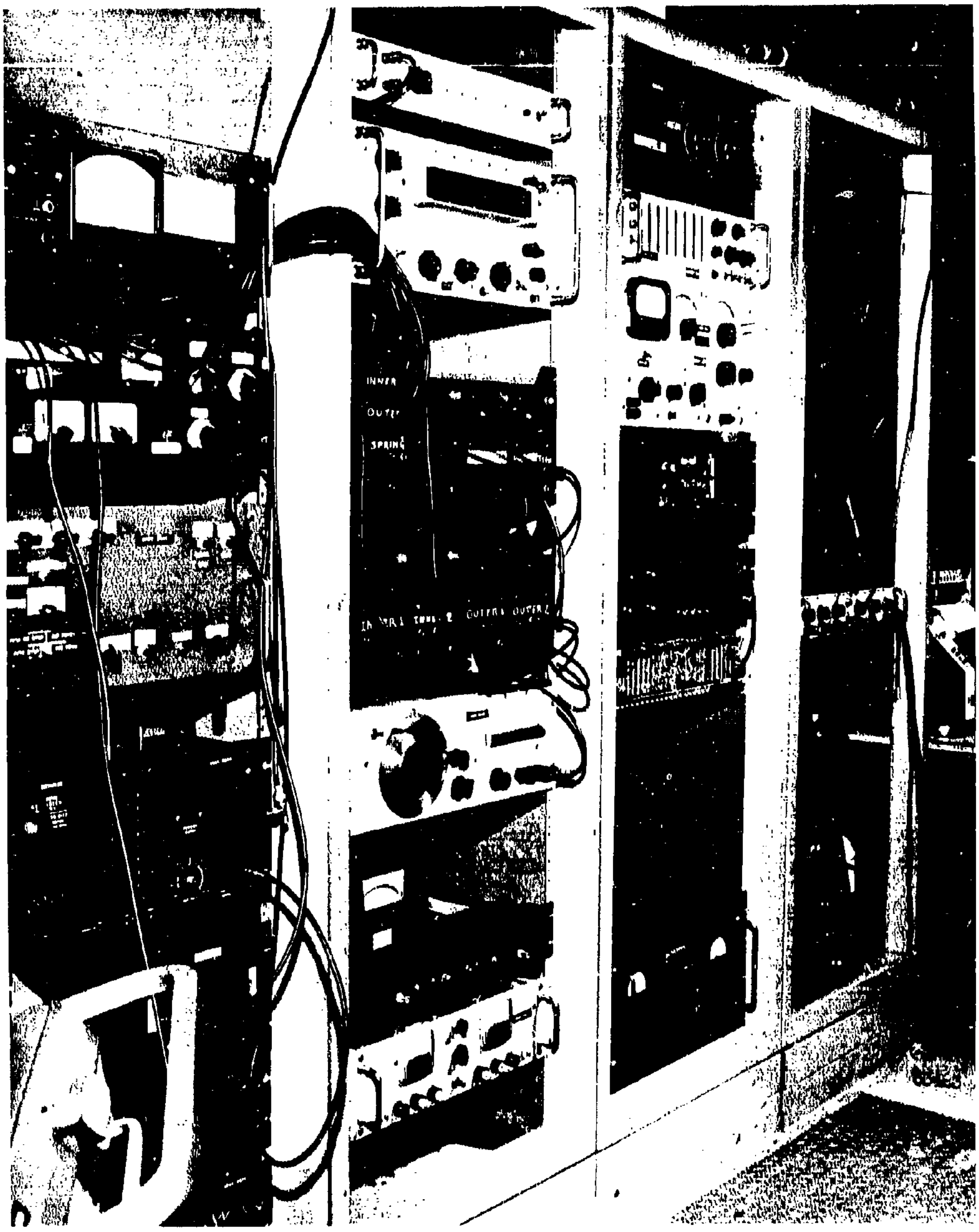

Fig. 16 - Spring deflection instrumentation

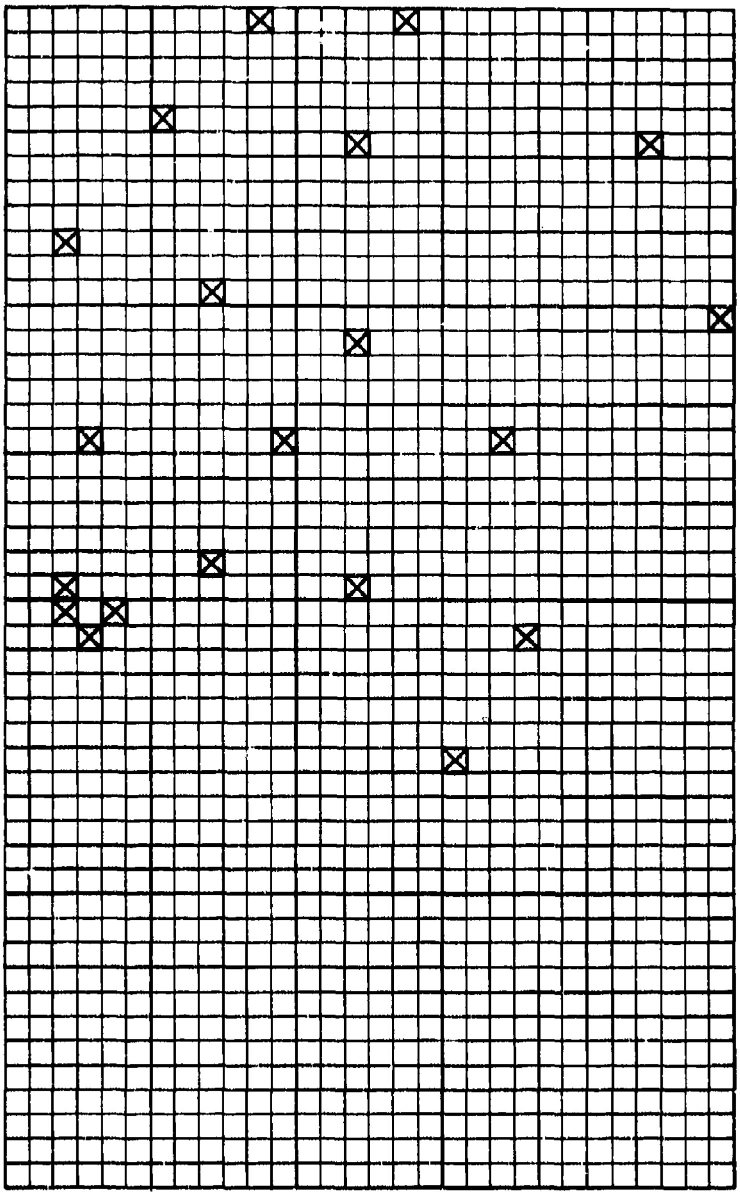

Fig. 17 - Distribution of instrumented elements in the array

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13. ABSTRACT (Confidential)

Acoustic tests of the completed ARTEMIS acoustic source were conducted in Northwest Providence Channel in November 1965. A rigid 190 foot hydrophone boom pivoted at the base of the array structure enabled stable and accurate positioning of hydrophones at points in a vertical plane from 2.5 degrees above to 22.5 degrees below the acoustic axis of the source.

The transfer function between the input to the amplifiers and the hydrophone output was measured over the frequency range from 300 to 500 hertz for two types of signals, continuous wave and pseudorandom sequences. Continuous wave measurements were made using conventional phase and amplitude measuring instrumentation whereas the measurements with pseudorandom sequences were performed with a cross-power spectrum analyzer. The cross-power spectrum analyzer was also used to obtain correlation functions between the signal input and acoustic output. Twenty transducer elements were instrumented with accelerometers and appropriate instrumentation was provided to permit monitoring of transducer element spring deflections, since the transducer springs are the critical factor limiting the allowable power input.

This report includes a description of instrumentation, test procedures, and analysis of the methods employed.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
ARTEMIS						
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Hydrophones						
Transfer function						
Continuous wave measurements						
Pseudorandum sequence measurements						
Cross-power spectrum analyzer						

UNITED STATES GOVERNMENT

Memorandum

7100-016

DATE: 22 January 2004

REPLY TO ATTN OF: Burton G. Hurdle (Code 7103)

SUBJECT: REVIEW OF REF (A) FOR DECLASSIFICATION

TO: Code 1221.1

REF: (a) "Project ARTEMIS High Power Acoustic Source", A.T. McClinton, R.H. Ferris, W.A. Herrington, Sound Div., NRL Memo Report 1205, 3 Aug 1961 (U)
(b) "Project ARTEMIS High Power Acoustic Source Second Interim Report on Acoustic Performance", A.T. McClinton and R.H. Ferris, Sound Division, NRL Memo Report 1214, 19 September 1961 (U)
(c) "Project ARTEMIS High Power Acoustic Source Third Interim Report on Acoustic Performance", A.T. McClinton, R.H. Ferris, Sound Division, NRL Memo Report 1273, 23 April 1962 (U)
(d) "Project ARETMIS High Power Acoustic Source Effect of Transducer Element Electrical Connection on Interaction in a Consolidated Array", A.T. McClinton, Sound Division, NRL Memo Report 1323, 4 June 1962 (U)
(e) "Test of Project ARTEMIS Source", R.H. Ferris, Sound Division, NRL Memo Report 1648, 15 September 1965 (U)
(f) "Power Limitations and Fidelity of Acoustic Sources", R.H. Ferris and F.L. Hunsicker, Sound Division, NRL Memo Report 1730, November 1966 (U)
(g) "Project ARTEMIS Acoustic Source Acoustic Test Procedure", R.H. Ferris and C.R. Rollins, Sound Division, NRL Memo Report 1769, 5 June 1967 (U)
(h) "Calibration of the ARTEIS Source and Receiving Array on the Mission Capistrano", M. Flato, Acoustics Div., NRL Memo Report 2712, Dec 1973 (U)
(i) "Theoretical Interaction Computations for Transducer Arrays, Including the Effects of Several Different Types of Electrical Terminal Connections", R.V. Baier, Sound Division, NRL Report 6314, 7 October 1965 (U)
(j) "Project ARTEMIS Acoustic Source Summary Report", NRL Report 6535, September 1967 (U)

1. References (a) thru (j) are a series of reports on Project ARTEMIS Reports by the Sound Division that have previously been declassified.

2. The technology and equipment of reference (a) have long been superseded. The current value of these papers is historical

3. Based on the above, it is recommended that reference (a) be available with no restrictions.

Burton G. Hurdle

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